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This paper has been prepared for publication in *Astronautics and Aeronautics*, a publication of the AIAA. The last half draws on an earlier paper prepared for the United Nations Association of the USA.

For a good many years now, engineers have foreseen a new generation of precision-guided weapons which could result in major changes in the posture and tactics of nearly every military power. But, as is so often the case, it took the practical demonstrations of those weapons in Southeast Asia and in the October War of 1973 to convince decisionmakers that a new generation of weapons was at hand.

For centuries most of the things shot by military men at their enemies have missed their target. The remarkable thing about the new generation is that it is now possible for forces to possess weapons in large numbers each of which has a high probability of hitting its target with a single shot. This article discusses the implications of these weapons, which are officially called "precision-guided munitions" or "PGMs." Usually, this simply means a bomb or missile that is guided in its terminal phase. Thus, the term includes many anti-tank weapons (including some which receive steering signals over thin wires) and air-defense missiles, as well as the laser-guided bombs which attracted so much public attention.

What do these developments mean for engineers?

First, consider some questions about U.S. national security which those of us who have been working on military projects have been asking: Do these new weapons mean that NATO is better able to defend itself against an attack by Warsaw Pact forces? Do they make it less likely that neither side will resort to nuclear weapons? Will precision munitions make more feasible the strategy of being prepared to use nuclear weapons in a limited way? How will the new techniques affect regional instabilities as thousands of modern weapons are purchased by newly rich oil-producing countries?

Then there are a number of questions that engineers are asking at a more personal level. Some are wondering what the advent of practical precision guidance at a distance means in terms of needed professional skills. What weapons systems will governments be ordering? What about the future of the penetrating airplane? The large nuclear-powered aircraft carrier? The big tank? What additional uses will be made of airborne platforms? And, most personal of all, what effect will these changes have on job security?

This article cannot answer such complex questions, but I shall try to give some background, and shall put forward some ideas about where the trends are leading. But, first, let us review what has gone on.

General awareness that something new has happened was triggered by the performance of the unpowered *Pave Way Laser-Guided Bombs* in Vietnam in 1972. With the help of a TV camera bore-sighted with a narrow laser beam on a pod-mounted platform, the weapons systems operator aligned cross-hairs and target image on a video display, thus illuminating -- or "designating" -- the target. A two-part kit, attached to MK 82 500-lb bombs or MK 84 2000-lb bombs provided steerable front fins controlled by a laser receiver that caused the bomb to home on the energy reflected from the target. In earlier systems the laser beam was aimed at the target from a spotter airplane, but a later version avoided mixups by designating from the F-4 bomb carrier itself. Excellent accuracies could be obtained, making it possible to destroy in one or two sorties a bridge span that might otherwise have required dozens. Judging from the aerial photographs released by the U.S. Air Force, the accuracy equalled or exceeded the requirements set in 1966: "CEP no greater than 25 feet; guidance reliability at least 80 percent."*

WHAT IS A PGM?

The original laser-guided bombs began to be called "smart bombs," along with similar TV-guided bombs. But, dismayed that the unguided bombs were being called "dumb," Pentagon officials soon decided on the name "Precision-Guided Munitions," and included rocket-powered and gun-launched rounds as well as bombs, with the word "munitions" implying detonation at the target.

The name was just catching on when the October War of 1973 showed the importance of precision-guided anti-tank and anti-aircraft weapons (and also showed the importance of taking their crews under fire). Here the Soviet *Sagger AT-3* wire-guided anti-tank missile was used in quantity against Israeli armor. Often mounted in sixes under a kind of steel umbrella on the BRDM-2 armored car, it weighs 11 kg, has a 2.7 kg warhead, and takes 25 seconds to reach its maximum range of 3000 meters.** That is

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*Quoted in deLeon, Peter, *The Laser-Guided Bomb: Case History of a Development*, The Rand Corporation, R-1312-PR, May 1974.

**_Flight International_, May 8, 1975, pp. 774-775.

long enough to allow the intended target to seek cover or to distract the guider by taking him under fire. I will say more about the anti-aircraft systems below. But before giving more examples, I put forward (though I am not sure we need it) a definition of a PGM:

> A guided munition whose probability of making a direct hit on its target at full range (when unopposed) is greater than a half. According to the type of PGM, the target may be a tank, ship, radar, bridge, airplane, or other concentration of value.*

By this definition the Japanese kamikazes of 1945 operated functionally as PGMs. A less well-known and rather bizarre example is given in a recent Soviet book.**

> During the Great Patriotic War dogs were used to destroy tanks. They usually attacked tanks from a distance of 150-200 m. As a dog dashed under a tank frontally or at a 45° angle the trigger of the explosive charge caught on the bottom of the tank and set off the fuze. Thus in the sector of the 160th Infantry Division in the vicinity of Glukhovo six dogs destroyed five enemy tanks.
>
> At Stalingrad, in the vicinity of the airfield, a squad of tank-destroyer dogs destroyed 13 tanks. At Kursk, in the zone of the 6th Guards Army, 16 dogs destroyed 12 tanks that had broken through into the depth of the Soviet defences in the area of Tamarovka, Bykovo, Hill 244.5.

Perhaps the term can be further defined by citing examples of weapons which most analysts would agree are PGMs, although the one-half hit probability may be obtained only by select crews operating under ideal conditions for some of these. You will notice that a very wide scope is included.***

Grail and *SA-7* are NATO designations for a Soviet anti-aircraft missile that can be fired from the shoulder. First seen by U.S. forces in Vietnam,

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*This definition is slightly modified from one given in my recent Adelphi Paper No. 118, *Precision-Guided Weapons*, The International Institute for Strategic Studies, London, Summer 1975. That paper treats many of these topics at greater length and includes a very condensed technical appendix on wavelength dependent factors.

**Biryukov, G., and G. Melnikov, *Antitank Warfare*, Progress Publishers, Moscow, 1972, p. 91.

***Unless otherwise noted, the data which follow are from the "World Missile Survey" of *Flight International*, May 8, 1975.

it was widely used in the October War. Fired in salvo at single Israeli aircraft, it damaged "the jetpipes of many A-4s, but [did not achieve] a very high kill ratio."* It has an infrared seeker and probably works best against subsonic aircraft flying lower than 1500 meters (though improved versions are said to be effective against faster and higher aircraft).

TOW BGM-71A is an American-made anti-tank missile of either 3000 or 3750 m maximum range. It is launched from a tripod on the ground, or (usually) from a vehicle, and guided semi-automatically by signals sent along two thin wires reeled off bobbins; these signals make it steer toward a line-of-sight created as its gunner simply follows his target through a telescope. The Soviet *Sagger AT-3* is similar in purpose, but requires more training, since its gunner must follow both missile and target, and must fly the missile into the target.

SA-6 (Gainful) is a larger, vehicle-mounted Soviet anti-aircraft missile guided by a dual-frequency radar, with guidance commands transmitted by radio.** Egypt, Syria, and North Vietnam also operate SA-6s.

Sidewinder AIM-9 is the family name of an air-to-air missile developed by the U.S. Naval Weapons Center. The AIM-9L is currently nearing production. It has an infrared seeker cooled by a blow-down gas bottle and weighs about 84 kg. Many Western countries use various versions of the Sidewinder.

Maverick AGM-65A is an anti-tank missile now carried by USAF close support aircraft. It is guided by a television camera in the missile's nose; once the flight crew lines up the cross-hairs of the sight they can actuate a lock-on switch and the circuits on board the missile automatically track the target. After launch, the aircraft can leave or take on other targets. This not only speeds up its rate of fire, but permits the aircraft to avoid close-in air defenses. A developmental version uses a laser seeker instead of television.

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*Ibid., March 14, 1974, p. A-12.

**For a better feel for how the SA-6 works as part of a system of guns and other missile types of complementary capabilities, see *International Defense Review*, No. 4, 1974, p. 450, for the chart, "The Anti-Aircraft Threat in Central Europe."

CLGP -- Cannon-Launched Guided Projectile is a U.S. Army developmental project for guiding a 155-mm howitzer round; the projectile carries a laser receiver which provides steering. The projectile is made to home on a spot from a laser illuminator (or designator) which could be operated by a nearby ground or air observer.*

GBU-15 -- Modular Glide Weapon System is a USAF development built around a winged 2000-lb bomb. As the name implies, its guidance modules can be switched according to the situation. The GBU-15 could use both DME guidance and the laser seeker devised for Maverick to steer an unpowered winged bomb to a target many miles away. Improved warheads would permit destroying hard concrete structures or runways.**

HARM -- High Speed Anti-Radiation Missile AGM-88A is a rocket-powered missile which homes on targets (like missile radars) which emit radio-frequency signals. It is a joint development of the U.S. Air Force and U.S. Navy.

Condor AGM-53A is a rocket-powered U.S. Navy anti-ship missile; it is now in pilot production. It can be guided in its terminal phase as a remotely piloted vehicle (RPV) by an operator on the mother aircraft, who sees a relayed television picture from the missile's camera. (Other guidance options are also being developed.)

Shaddock SS-N-3 is the NATO designation for a Soviet anti-ship cruise missile; *Shaddock* and its derivatives can be launched from surfaced submarines or from surface vessels. Originally one saw estimates of 200 n mi range, but improved technology would seem to permit much longer aerodynamic ranges. *Jane's*** notes that this missile, in some cases, requires aid in guidance from an aircraft, and that "there is evidence that the missile may be programmed for shorter ranges and have an active radar terminal homing capability." It is said to carry either an HE or a nuclear warhead.

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*Schlesinger, J. R., *Annual Defense Department Report, FY 1976 FY-197T*, p. III-69.

**Currie, Malcolm R., *DOD Program of RDT&E, FY 1975*, p. 4-44 and 4-45. Also *Aviation Week*, 10 December 1973, pp. 14 and 27, January 1975. p. 107 ff.

***_Jane's Fighting Ships 1974-1975_, Jane's Yearbooks, London, p. 531.

Pershing II is a U.S. Army nuclear ballistic missile, with a range of 400 n mi, in development. Its inertial guidance system can be supplemented by a terminal homing reentry vehicle which uses a radar map-matching technique. An option will be a low-yield earth penetrator warhead for use against hard targets. Former Secretary Schlesinger pointed out its possibilities for reducing collateral damage and for replacing the more vulnerable QRA aircraft.*

SLCM -- Sea Launched Cruise Missile YBGM-109 and YBGM-110 is a U.S. Navy developmental program which includes a tactical anti-ship version and a longer range strategic version. The tactical SLCM uses radar seeker guidance from the earlier Harpoon, but extends Harpoon's 60-plus-n mi range to about 300 n mi. The strategic version would have the even greater range of 1300 to 2000 n mi; it would supplement carrier-based strike aircraft. It carries an inertial guidance system which is corrected periodically by a terrain contour matching device. This permits great accuracy in attacking targets whose location is known with respect to known terrain, even though they may be quite distant from the launch point.**

Terminally-Guided ICBMs are presaged by the U.S. maneuverable reentry vehicle developments and the Soviet SS-NX-13.*** These could lead to reentry vehicles steered by terrain contour matching or map matching which might be accurate to less than a hundred feet. Since payloads of advanced HE warheads weighing 2000 lbs. or so could be carried, even moderately hard targets could be destroyed without using nuclear weapons.

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Thus the variety of precision guided munitions is great. Some -- like the surface-to-air and air-to-air types -- have been around for years.

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*Schlesinger, op. cit. (FY 1976), pp. III-66 and III-67; Currie, Malcolm R., *DOD Program of RDT&E, FY 1976*, pp. VI-25 through VI-27.

**See *Hearings on S. 920*, Part 10, Committee on Armed Services, United States Senate, April 1975, pp. 5130 ff.

***_Soviet Aerospace_, November 18, 1974, p. 85, quotes Dr. Malcolm Currie as saying that this is a ballistic missile which "we believe has maneuvering based on radar homing" that lets it attack surface ships.

For others, the novelty is their simplicity or their producibility. RPVs are included in the category if they are intended to hit a target, and these seem to be of increasing military importance.

Let me now put forward two statements that make some basic observations about PGMs:

Statement One:

> Accuracy is no longer a strong function of range; if a target can be acquired and followed during the required aiming process, it can usually be hit. For many targets hitting is equivalent to destroying.

The second may be just as important:

Statement Two:

> Precision-guided munitions can now be mass-produced in great quantity; for many of these the cost per round ranges from the order of $2000 to the order of $20,000. Moreover, many can be operated by ordinary soldiers.

Examination of the properties of PGMs gives an interesting insight into the obsolescence of some familiar ways of categorizing weapons and missions. For one thing, the familiar labels "strategic missions" and "tactical missions" may now impede thought more than they help it. Contemplation of the variety of jobs that can be done by such types as Shaddock, Condor, the SLCM, and terminally-guided ICBM confirms this view. Tanks may be efficiently hit by RPVs launched from big bombers, "tactical" attack submarines could send cruise missiles against enemy ICBM silos, and terminally-guided ICBMs could be used to interdict troop movements. Moreover, as mentioned in Statement One, munitions which can be terminally guided can be nearly as accurate at great ranges as at short ranges. They are quite indifferent to the means of transport that brought them to the launch point. Quite similar 1000-mi cruise missiles could be launched from a land vehicle, a small ship, a "strategic" SSBN, or a B-52. Moreover, identical vehicles could carry nuclear payloads or enough non-nuclear explosives of modern design to do many of the more precisely defined military jobs. There would seem to be a strong suggestion in all this that future military forces will not be designed around their means of transport -- air, land, or sea -- nor around the old designations of strategic forces and tactical forces, but rather

around the kind of targets to be found and attacked, the numbers of those targets, how they are located, and the problems of reaching them. For example, the job of attacking airbases might be handled by PGMs launched from the land or the sea, as well as the air, and one can see that it might be institutionally efficient to allocate funds for these systems from a common task-oriented budget.

PRECISION WEAPONS FOR LARGE-SCALE NON-NUCLEAR WAR

Recalling Statements One and Two, consider some of the implications of the new precision weapons for large-scale non-nuclear war.* (For example, a war involving NATO's Central Front.) To begin, these implications will be stated in simple terms, and as if PGMs would work about the way their designers intended. Then some complications will be mentioned, and some comments on the degree to which the simple ideas apply in the practical world.

First, it will probably become much less desirable to concentrate a great deal of military value in one place or in one vehicle. For instance, a combatant would be less likely to want to place a large fraction of his capability at risk as he exposes a single transport airplane, or a single surface vessel in the Mediterranean. He would probably prefer to have *many* inexpensive lightly armored vehicles instead of *fewer* more expensive tanks. Consider that the attacker has a limited number of PGMs, any one of which has a high probability of destroying either a valuable or a less valuable target.** It is better to force him to spread his PGMs over many targets: he will strain *his* supply more and will face the difficulties of target acquisition more times.

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*Space does not permit a discussion of the equally important, but more speculative, topic of precision weapons in limited nuclear operations. This topic will be covered in a forthcoming book being edited by Johan Jörgen Holst and Uwe Nerlich with the working title *Technology, Politics, and the Defense of Europe;* see especially the chapter by Henry Rowen and Albert Wohlstetter. Other aspects are covered there in my chapter "Precision Weapons: Lowering the Risks with Aimed Shots and Aimed Tactics," now available as Rand Paper P-5495.

**This is not meant to imply that, for example, NATO defenders would, overall, have more PGMs than Warsaw Pact attackers. In fact, the reverse may turn out to be true, and quantitative studies of that confrontation would be of great importance.

Second, concealment will become much more important, and thus concentrations of many vehicles or men will be less practical. Concentrations will usually be easier to see and to keep track of than a larger number of independently moving targets. This is critical, because with PGMs seeing a target can usually lead to its destruction. Smallness and mobility will make hiding easier, and both these qualities are consistent with the thrust of the first point. However, before arriving at a final judgment, one must consider the degree to which the concentration can be sheltered, or protected by active defenses, by comparison with sheltering or protecting dispersed elements.

This is a point of major importance in assessing the balance between an offense and a defense because a classical offensive tactic is to attempt overwhelming superiority in a narrow sector by concentrating forces there.

There have always been reasons why a commander should worry about having great force concentrations, but even the availability of tactical nuclear weapons did not, in practice, result in a full set of corresponding actions to decrease vulnerability. The tactical planner may have had some excuse for inaction because of the uncertainty about whether tactical nuclear weapons would be used. For PGMs, though, there is no question of their being used, given fighting, and no planner can any longer responsibly pass over their effect on his vulnerabilities.

Third, even small units can be very powerful when equipped with PGMs or designators that can call in and guide remote PGMs; these units might carry air defense weapons as well. In land warfare the natural size of many independently mobile squads might be 3 or 4 men, and these squads might get around by walking or by using inexpensive vehicles, *not* expensive tanks.* There would be a problem of protecting such units from conventional overrunning attacks by infantry, but their mobility and their ability to call in PGM firepower -- or remotely launched missiles with area coverage -- would help.

Fourth, a fraction of the munitions used need not be hauled all the way to the front in systems where the units up front serve as spotters and

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*The author first encountered this and a number of related ideas in discussions with T. F. Burke of The Rand Corporation in 1972. Burke has developed these ideas in lectures at the U.S. Army War College and other service schools; no published version is available.

designators; the munitions they call in might be ground-launched or air-launched from tens of kilometers farther back. Over a wide range of types of conflict, the weight of munitions delivered to the launch point *for a given effect* on enemy forces need not be nearly as great as in the past, because each round fired has a high probability of killing its targets.

Fifth, and relevant to the ideas at the start of this paper, is that a natural consequence of having a high hit probability is that collateral damage to civil populations and economies is likely to be much less with precision munitions. In the NATO case, this prospect may have substantial consequences over the long run for German attitudes toward preparations for actual fighting on German territory in contrast to preparations that are part of a tripwire strategy. But a German concession would be much less likely if precision-guided "mini-nukes" were under consideration, a factor which is in addition to the negative aspects of mini-nukes in blurring the firebreak, as mentioned below.

Sixth, ground-based anti-aircraft defenses have become extremely lethal. The Soviet SA-6 is an example of a powerful way to keep air off the backs of mobile units, and proves the operational feasibility of this class of weapons. The Yom Kippur war showed how such air defenses, as well as systems like the ZSU-23-4 four-barrel gun and the hand-held SA-7 are likely to be proliferated in great numbers over the area occupied by ground troops.

The lighter of these classes of weapons may well be added to the mobile squads mentioned above, and the heavier may travel with them, along with the anti-tank weapons. The end result of this trend may be a shift in how ground forces are protected against enemy air. More of the protection is likely to come from ground-based anti-aircraft defenses, and less from attacks on enemy air bases and air-to-air duels.

Those six trends will clearly have a major effect on forces and tactics for non-nuclear war. But the consequences of PGMs are too important for an opponent to permit them to be used as their owners wish; in addition, there are a number of practical complications.

To begin with, the technology for accurate guidance that is most fully developed requires transmission through the atmosphere in the visible

spectrum or near the visible spectrum. Simple radar guidance is not sufficiently accurate. Thus many present systems do not work at night, or through smoke, clouds, or heavy dust. Systems using long-wave infrared will be in widespread use by 1980. These will be useful at night and will do fairly well through smoke, dust, and haze, but they will be fairly expensive and may be significantly harder to maintain in the field. Nevertheless, the majority of PGMs will require clear daylight for many years.

Another problem is command and control. In past wars, commanders tens of miles behind the front concerned themselves with entire enemy divisions, or, at the smallest, battalions. With PGMs a division may consist of 500 separately targetable, individually moving objects. Rather than succumb to the temptation to handle this problem with data processing technology from a centralized operations room, my own judgment is that much of the solution should be found in the delegation of authority and the use of standing procedures, even though the officers doing the detailed weapon control may well be many kilometers away from the target.

A third complication is that the units near the FEBA become too small, or too mobile, or too well hidden to target, then the natural tendency will be to target depots and other valuable concentrations in the rear-area support structure. Thus, there is likely to be a shift to targets farther and farther back as the missiles able to handle this job become more practical; *finding* the targets is a crucial part of the job. Let us consider this with special reference to NATO.

For some years this shift might find NATO at a relative disadvantage -- since it has been the NATO style, and especially the American style, to build great depots and to rely on a much larger support structure than the Warsaw Pact forces use. Quite apart from any argument for making forward forces less vulnerable, the simple fact is that, as stand-off missiles get better and more practical, there must be actions to reduce the vulnerability of rear-area concentrations, even those several hundred kilometers back and formerly thought safe from any but the most determined air attack. Like several other moves to become better prepared for PGMs, this would

also make NATO less vulnerable to nuclear attack, and thus help make a nuclear attack less attractive.

A further consequence of shifting attacks to targets farther back will be some new attitudes toward sanctuaries. For example, the vulnerability of hardly any of NATO's rear area targets (except atomic-capable aircraft) has been a major subject of concern. Now those concerns must be extended, and priorities for protection calculated, for *any* concentration of military forces or equipment targetable by stand-off weapons.

As noted, counters to PGMs will take on a very high priority. Concealment and camouflage may work very well against present PGMs. When this is the case the attacker might logically revert to area barrage fire or to area bombing. Secondly, crews of most present PGMs are vulnerable (as are airborne platforms) and will be the focus of counter-attacks. And thirdly, new designs of armor may force up warhead sizes -- which with shaped charges can now be quite small.

Consider again the first point of this section: there are complex questions of balance raised in the choice of "many inexpensive" instead of "fewer more expensive" vehicles. One has to ask about whether the inexpensive vehicles will have the needed speed, range, and payload. Will the operating manpower required make the "many" less desirable? Will only the "few" be able to mount effective countermeasure devices?

And there are problems with the avoiding of concentrations. Dispersed forces may be inefficient to operate. As to the value to the offense of "overwhelming superiority in a narrow sector," can this be done by calling in offensive PGMs from far away, concentrating the firepower, if not the forces?

More reasons could be given why PGMs might not work as their users hope, or why their consequences are more complicated than the six trends I have listed. Simple analyses will not tell all we need to know to answer some very important questions. From the point of view of NATO, some thoughtful and rather complex analyses need to be made, preferably on a joint basis as between European and Americans. These analyses

need to consider force-on-force, not just one-on-one. They need to consider how the new-style forces might affect plans and intentions -- as well as conflict outcomes. They need to treat some exceedingly important questions about Soviet strategy with respect to the West, and NATO's ability to defend itself and to deter attack: Is the present design of the Red Army appropriate to the task of an anti-NATO offensive? Would prudent Soviet military judgment call for a less tank-heavy posture -- a ponderous move -- before certifying readingness to attack? Will NATO defense be adequate without resorting to nuclear weapons? These are among the most important questions to bear in mind while considering the relation of PGMs to nuclear warfare in the next section.*

PGMs AND THEATER NUCLEAR WARFARE

From the U.S. point of view a major value to be derived from NATO is that its solidarity appears sufficient to the Soviets to deter an attack which might lead to a theater nuclear conflict, and which could lead, in turn, to an intercontinental nuclear war. The latter, so improbable that war gamers often apologize for those elements of their scenarios which lead there, has two properties of interest here; it has such terrible potential that even improbable triggers deserve careful attention, and, second, intercontinental nuclear war could seem much more likely if there had been a major nuclear exchange in Europe, especially if most of the European Allies were going under and U.S. forces had suffered heavy casualties. This chain of events could be the more dangerous if communications were unclear, if bluffs were misunderstood or if leaders were inept.

There is, I believe, a new element of risk. Near the end of this paper I discuss how modern weapons -- which are both numerous and releasable -- are likely to speed up the rate of destruction in non-nuclear war, as well as the dollar-rate of munitions consumption. This faster rate could lead to

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*In the previously cited Adelphi Paper I treat several implications of PGMs omitted here: the large number of highly portable anti-tank and anti-aircraft weapons likely by 1980, the war of seeing and hiding on NATO battlefields, and the priority that will be given to attacking PGM crews. Some deficiencies of PGMs over the near term are listed, and possibilities for overcoming these deficiencies are suggested.

sudden surprises or to a pause -- at which time there might be a heightened temptation to escalate to nuclear use. But if we anticipate this pause, and especially if both sides have observed limitations, the pause could lead to de-escalation and negotiation.

It is distressing, in a time when both Soviet and U.S. forces possess huge theater nuclear forces, that the strategy for their contingent use has not been fully thought through, and that there is no general agreement on the specific purposes many of these weapons should serve.

Laurence Martin suggested* how this came about:

> Tactical nuclear weapons fell into disrepute with those who governed American strategy. This helped to inhibit the emergence of a coherent doctrine for their use and halted the development of new tactical systems specifically designed to execute well-defined tasks. Nevertheless, the demands of the armed services and the political need to reassure allies who had been taught that the stationing of tactical nuclear weapons in Europe was necessary to link them to the American deterrent ensured that the deployment of nuclear weapons continued energetically until NATO reached the legendary figure of about 7,000 for local use. In this haphazard way the present huge arsenal was deployed in Europe, unrelated to any well-accepted strategic doctrine and in many respects ill-adapted, even technically, to the execution of such military tasks as have been defined for it.

In 1974 Congressional concern over this same point was shown by the Nunn Amendment** which

> . . . prohibits any increase in the number of U.S. tactical warheads in Europe except in the event of imminent hostilities and directs the Secretary of Defense to study our tactical nuclear policy and posture to ensure that it is coordinated within the Alliance and is fully consistent with a strong conventional defense. The study must also consider the number and types of weapons that could be reduced.
>
> The present U.S. posture on tactical nuclear weapons in Europe does not appear to reflect current and comprehensive policy determinations; it seems to be more of an accumulation of kinds and numbers of

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*In his "Theatre Nuclear Weapons and Europe," *Survival*, Nov./Dec. 1974, p. 268.

**_Report on S. 3000, Committee on Armed Services, United States Senate_, May 29, 1974. For the Defense Department's response see *Survival*, Sep./Oct. 1975, pp. 235-241.

> weapons over a long period of time. The number, dispersal and variety of tactical weapons and the high alert status we maintain is probably a destabilizing factor lowering the nuclear threshold. The committee believes that NATO needs a convincing nuclear deterrent but that we cannot afford the unnecessary risk of too many nuclear weapons in Europe or too great a readiness to use them.

The matter to be discussed in this paper, though, is the interrelation between PGMs and nuclear warfare. The situation just surveyed leads me to suggest three points for examination:

- What effect will PGMs have on the nuclear threshold? Is the conventional defense of NATO now credible? It appears that non-nuclear PGMs are effective enough to do many of the jobs now assigned to nuclear weapons. Just which jobs?
- Where nuclear weapons are used, precise delivery will permit smaller yield warheads. Damage will be more calculable. What effect will this have on the stockpiles of the nuclear powers, on their rules for control, and on their strategies?
- Given the major changes in stockpiles and posture implied by these adjustments and by the new technology, and given the inconsistent and vague basis of current U.S. and NATO theater nuclear strategy, what can be done to formulate a new strategy? Can clarity of purpose reduce the dangers?

Consider the first question: Will PGMs raise the nuclear threshold? Preliminary studies have shown that PGMs have a good chance of stopping a tank thrust without resorting to nuclear weapons. Future types, especially RPVs, can be quite potent in attacking targets in rear areas, and may be adequate substitutes for many middle-range nuclear strikes by QRA aircraft.* Nuclear-tipped air defense missiles are likely to account for a decreasing share of kills as weapons like Grail, Gainful, Stinger, and Roland are

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*A fraction of the NATO-assigned nuclear-capable aircraft are kept on Quick Reaction Alert (QRA), ready for nuclear strike missions.

proliferated. New types of non-nuclear mines could replace atomic mines in many spots. But these are impressions, and it would be useful to see more specific studies comparing each of the theater nuclear weapons with the most effective non-nuclear alternative. Nonetheless, it seems abundantly clear that these developments will result in a higher nuclear threshold.

Second, if nuclear weapons are to be used, can yields be lower? Military forces might use nuclear warheads for four reasons:

(1) They compensate for inaccurate delivery or uncertain target location.

(2) They can destroy soft targets over a wide area.

(3) They can damage hard targets.

(4) They would have a tremendous, but unpredictable, political effect.

It is my own view that military conservatism, applied in several layers, has resulted in higher-than-necessary yields because of (1) above; with the new technology for both guidance and reconnaissance, yields could be brought down. As to (2), the new non-nuclear PGMs are available in such large quantities that they could reasonably substitute for smaller numbers of nuclear weapons in many cases. On the other hand, the dispersal of forces that PGM use encourages may increase the incentives to use multi-kiloton nuclear warheads for area coverage, especially if there is a time urgency.

Citing both military and political values, some planners have proposed the use of "mini-nukes" -- weapons with very low-yield warheads, so low as to be nearly interchangeable with non-nuclear warheads. Advocates of "mini-nukes" believe that any American nuclear contribution should be designed to repel an attack at its outset, and that the early release of small yields would be more credible and result in less collateral damage. Opponents of this view question the military effectiveness of such a posture* and point to the problems of release and control if very early use is entailed.

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*For example, it would take kilotons to deal effectively in one burst with a typical area target like an armored regiment. "Mini-nuke" usually means a sub-kiloton weapon.

They also question whether the Soviet Union, which seems to be planning nuclear use on a large scale, indiscriminate basis, would be deterred by NATO "mini-nukes." But, most of all, they point out the grave uncertainties as to where nuclear use, even though limited, might lead. In any event, the United States has stated that it does not intend to develop "mini-nukes."*

Now to the third point: What can be done to formulate a new theater nuclear strategy in these times of changing postures and changing technology? I believe that there will never be a better time. The new technology has given us that ability to avoid collateral damage while effectively executing precise combat operations whose intent can be clearly understood. We need to design a strategy aimed at terminating or de-escalating conflict. To make our intent clear, we should have dual criteria with respect to damage: damage to intended targets must be maximized and damage to non-targets minimized. Non-nuclear PGMs meet these requirements and serve a conflict-limiting strategy well. But the consequences of even the most limited use of nuclear weapons are unknowable (given the unknowable Soviet reaction) and this makes their use undesirable if the goal is to limit conflict.

But as long as NATO must count on the deterrent effect of theater nuclear forces, the previously cited article by Professor Martin gives some criteria:

> This force must match, and therefore attempt to deter, the introduction of the Soviet Union's own theater nuclear weapons and, if need arises, must be used in a conspicuous, deliberate fashion, . . . Such a NATO nuclear force must attempt both to halt the aggressor's advance and to issue such a warning of dire prospects that the combination of momentary defeat and prospective disaster

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*On May 23, 1974 the United States made a statement to the Geneva Disarmament Conference which "gave assurance . . . that it would not develop a new generation of miniaturized nuclear weapons that could be used interchangeably with conventional weapons on the battlefield." In an interview, Dr. Fred C. Ikle, director of ACDA, said, "We have no intention to move in a direction that could blur the distinction between nuclear and conventional arms" (*New York Times*, May 24, 1974.)

> will impel him to terminate hostilities on terms acceptable to the West. To be satisfactory, the forces providing such an option to NATO must be quickly responsive, fully subject to the highest possible level of political and military control, and impervious to seizure or sabotage in peace or war.*

In the present discussion, the question to ask is what effect precision delivery has in meeting Martin's criteria, and to note that the property of good accuracy at full range facilitates the centrally controlled covering force which Martin proposes. Remote nuclear PGMs would be easier to protect from sabotage or attack.

In sum, it is my view that PGMs reduce the need for theater use of nuclear weapons, that precision guidance of *any* weapon permits precision in what is destroyed, and that as long as we need theater nuclear forces, a shift to less vulnerable delivery means, to central control, and to a clear and mutually understood strategy can reduce dangers for NATO and for the United States.

NON-NUCLEAR PGMs AND THE SMALLER STATES

Some years ago it would have been out of the question for most small countries to do much about repelling enemy air attacks. Nor would those in exposed locations have had much chance of stopping a thrust of armored units. But the new style of arming goes a long way toward making the small countries more defensible against those kinds of attacks.

Because many of the new weapons have a relatively short range, local geography and climate will have much to do with how well they work. For example, it is particularly relevant to study the canalization of attacks in considering the use of anti-tank PGMs in halting attacks on Northern Norway and on Iran. The clear weather and open spaces of Iran make reconnaissance, perhaps by RPV, more important to its defense than in the case of Norway. Quite a different problem would be faced by The Philippines should they feel threatened by a mainland force:

**Survival*, Nov./Dec. 1974, p. 272.

they would need anti-aircraft PGMs and a combination of overwater reconnaisance and anti-ship PGMs (or RPVs). But the important point here is that even modest military establishments could support useful defensive forces in all these cases.

By the same token PGMs are likely to be useful to terrorist groups. While there have been only a few incidents or near incidents so far, it seems unlikely that recipient states will be able to keep PGMs in some numbers out of terrorist hands. Airliners, trains, ships, and places of public assembly are likely to be targeted. At the moment, direct solutions do not seem at hand, and chances are that our society will just have to adapt to this distressing extra peril. Airport security zones will have to be moved back, resembling those of SAC bases more than the inspections now in effect. Larger aircraft and land vehicles will come to be regarded as more chancy. Public figures will have to travel with more stealth (and at greater cost to their taxpayers).

Returning now to uses by established smaller states -- would these, or similar, weapons be used to support an offense? Most of the present generation of PGMs is specifically designed for defensive uses, but some future longer range weapons are likely to be useful to the offense when one small country attacks a neighbor, particularly a neighbor whose forces or valuable resources are located in only a few places. Another offensive use may be found where the local geography is suitable for leap-frogging tactics. In a surprise move the attacker might suppress defenses, then seize and hold a key point, defending it heavily with anti-tank and anti-aircraft PGMs. Thus, for the small countries, where the averaging effect of large numbers is less important, clever tacticians may eventually put the new weapons to offensive use.

For Americans, of all the prospects for changed military situations in the smaller states, the most urgent to understand are those for the Middle East. The next section examines certain aspects of these.

ARMS TRANSFERS TO THE OIL PRODUCING COUNTRIES OF THE MIDDLE EAST

By all odds the most important developments in international arms transfers are the increased purchases by the oil producing countries of the Middle East. Just in the past year Iran and Saudi Arabia each tripled

their military budgets; Iran now spends more money on arms than the United Kingdom. Iran already has or is buying 80 F-14 Tomcats, Phoenix missiles, Boeing tankers, 1200 Chieftan tanks and 500 U.S. helicopters. They already have 150 F-4 Phantoms. Saudi Arabia and Kuwait are buying F-5E Freedom Fighters, Mirage IIIs, and modern transport airplanes. The Soviets are reported to be offering MiG-25s to Kuwait.*

A fertile field for study is to estimate the defensibility of some of these countries with substantial numbers of anti-tank and anti-aircraft PGMs, with the former made more effective by the conjoined use of modern scatter mines which would slow and channel advancing tanks. (My guess is that some of us who read these words will find ourselves making such studies in the employ of Arab countries before the decade is over. Mercenaries, from truck mechanics to systems analysts, are likely to be a notable feature of the late 70s. There just are not enough suitable people on hand in these countries to operate the forces likely to be bought.)

The pattern so far suggests, however, that only a fraction of the arms purchases by Middle Eastern countries will be PGMs. Fighter-bombers and helicopters connote more prestige, and may be used for internal policing. So we may have a pattern of almost offsetting purchases by potential adversaries of offensive weapons and the PGMs to repel the same weapons.

I will leave it to other discussions to draw most inferences from this new arms spending pattern. But it is clear that while there will be multiple sellers and multiple buyers, this will be a buyer's market. Other resource-rich countries of the Southern Hemisphere may join the Arab states in spending more on arms. Countries like France, Sweden, and the U.K. will be forced by circumstances to take a very aggressive role in marketing arms. This market is likely to be a major factor for most U.S. arms producers, as well. There will be a lively second-hand market for years to come. An important question for the present discussion is: Should the NATO powers encourage the inclusion in this trade of as many non-offensive weapons as possible: anti-tank PGMs, anti-aircraft PGMs, mines, transport aircraft, etc.?

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*See *The Military Balance, 1975-1976,* and *The Middle East and the International System,* Part 1, Spring 1975, Geoffrey Kemp, "The Military Build-up: Arms Control or Arms Trade," in Adelphi Paper No. 114, both from The International Institute for Strategic Studies, London.

An additional prospect of concern is the extent to which the new weapons will be produced in new places. Many PGMs can be produced without a great industrial base. We can expect both marketing countries (like Switzerland) and some buying countries (like Iran) to set up new production facilities. This spread of production will be facilitated by a trend to regard payload design as separate from vehicle design. PGM design generally, and micro-electronic component design specifically, encourages this trend.

All of this prospect of the spread of effective arms leads to two more general questions for the arms controller. First, can the traditional arms producing countries, which tend to have stable military policies, exercise some element of control over third-country use of the weapons they produce? This might be done through the control of spare parts, through retention of key force elements (nuclear enrichment facilities, for example, or the reconnaissance elements of a weapon system). In other times, devices like PAL (the permissive-action link that serves to lock up nuclear warheads) could be contemplated, but they hardly seem likely in a buyer's market.

The second question is to ask whether PGMs, on balance, will be a stabilizing force. Will the third-world purchase of PGMs lead to strengthening defense capability more than offense capability. Will PGM purchases by one third-world country promise to negate the offense weapons purchased by a neighboring country, effectively neutralizing some of the expected arms build-ups? This question can be considered more fully after considering the topics discussed in the next section.

PROSPECTS FOR ARMS CONTROL

Central to any discussion of arms control prospects with respect to non-nuclear PGMs is whether or not this hypothesis is true:

Non-nuclear PGMs are advantageous to the defender.

Many of the early discussions on the implication of PGMs concluded that this hypothesis was, in fact, true. Consider some of the ingredients of the argument.

Target acquisition is the key to the successful use of PGMs, and it is much easier for a defender to hide than for his opponent who is moving through unfamiliar terrain, without the opportunity to prepare his positions. Earlier, we have noted how the classic offense involves the massing of forces in order to have a local numerical advantage. Massed forces will clearly be more difficult to conceal than scattered forces. Also on the defender's side is the possibility that the relatively light PGMs can be moved quickly to where they are needed -- perhaps by helicopters -- while heavier systems, including tanks, might arrive too late. For air defense PGMs, the defender has the advantage of the great contrast of looking at a hot solid object against a relatively blank background.

On the other hand, in non-nuclear conflict, massed forces may still achieve their ends by outnumbering the defense firepower (for example, systems like TOW are rate-of-fire limited). Also, as PGMs become more and more successful, more and more effort will go into countermeasures against them. For the current generation, relatively simple countermeasures to obscure offensive forces -- like smoke -- and the use of camouflage may be effective. There are also tactical countermeasures, classically including an infantry sweep in advance of a tank thrust, where the infantry is charged with taking PGM launch positions. Similarly, artillery barrages are likely to be effective against the less well protected PGM launchers. Many other kinds of tactics might work: deception, surprise, and fast moving leap-frogging thrusts.

Naturally, the defender will have tried various fixes for his deficiencies. Thus, the situation is the familiar one, as in most military activities, of measure and countermeasure.

We have already noted that most current non-nuclear PGMs are not well-suited for an offense, but that it is quite likely that many offensive military tasks can be handled by future PGMs, especially by those designed for longer ranges. For example, in the 1980s the mission now given to strike aircraft of attacking depots and airfields 50 to 250 km behind the FEBA is likely to be given to PGMs or RPVs. With respect to U.S. forces, by the mid-80s many systems designed for attacks on fixed targets may get guidance accurate to better than 10 meters, for example,

from the satellite-based Global Positioning System (GPS). It is also quite likely that PGMs specifically designed to suppress defending PGMs will be more highly developed.

Thus, it is not very easy to forecast just whether the offense or the defense will come out ahead over the long run. However, for the next 5 or 10 years it seems very likely that PGMs will give a substantial advantage to defenders in a non-nuclear war.

There seem to be two main ways in which the advent of PGMs could form the basis of arms control agreements. The *first possibility* depends strongly on the arguments just outlined, because if some of the major offensive weapons -- tanks, fighter bombers, nuclear-powered aircraft carriers -- are likely to be made less useful by PGMs, than nations would be much more willing to slow their introduction into forces, or even to abandon existing equipment. Consider the incentives. The simplest and most obvious is saving money, if a case can be made that defensive PGMs make these costly systems less effective. Then, several of the major powers may wish to slow the spread of local instabilities, which would be hastened by an emphasis on offensive arms. The major powers might find that a flow of offensive arms to client states would seriously increase the prospects that they would be involved by that client, against their own long-term wishes. Finally, and perhaps most important, there is the danger that the spread of offensive aircraft, and of long-range PGMs, may be coupled with the increasing prospects for nuclear proliferation. The question is whether both parties would find their strategic objectives well served by devoting most of their resources to defensive postures employing the newly effective weapons.

The *second possibility* for arms control would derive from the accuracy of the new weapons, which, we have noted, would lead to less collateral damage. The prospects for obtaining excellent military effectiveness with PGMs, while at the same time avoiding substantial damage to non-military targets, could lead to agreements -- possible implicit -- which would strictly limit civilian damage. After all, for many years military campaigns were carried out with mutually acceptable rules which called for

keeping the destruction limited to the battlefield. But unlike agreements which affect equipment inventories, such rules could be abrogated with little lead time, and, from the U.S. point of view, an implicit agreement might serve best. In any event, now that this may again be an efficient way to operate, as well as one which is morally attractive and to the mutual benefit of both adversaries, there would seem to be a good prospect of such rules of conduct among the major powers.

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It would seem that the questions about asymmetries with respect to the offense and defense are both researchable and relevant. So are specific calculations for various localities on the lowering of collateral damage. This is a goal toward which research funding should be directed.

A specific note of urgency is given to all of these considerations by the prospect, outlined in the preceding section, for substantial flows of arms to the Middle-Eastern nations. While not minimizing the importance of attempting to control the situation, nevertheless it is my own feeling that the prospects of success have been diminished greatly by the new flow of capital to the oil-producing countries.

SPECULATIONS ON DEFENSE INDUSTRY TRENDS

At the outset I raised a number of questions, including some questions about the nature of the defense industry ten or twenty years from now. Having given some flavor of the unknowns and cross currents so that the reader knows how speculative they must be, I put forth here several surmises about trends.

Defense procurements in the 1980s will probably shift away from expensive multi-function penetrating aircraft with tightly articulated weapons systems wound into their airframes. Big military aircraft will be designed as non-penetrating platforms to accommodate stand-off PGMs and RPVs, while smaller relatively simple aircraft may still be used for penetration missions or in less hostile arenas.

Perhaps there will be a shift away from the big engineering sections in airplane company engineering hangars, where hundreds of engineers work in coordinated teams, toward more numerous (but smaller) design groups working on cruise missiles, RPVs, satellite payloads, or small rockets. The big teams may still be needed, but less often, since the big aerial or space launch vehicles, like aircraft carriers, will be updated by changing their payloads. Thus, a greater fraction of engineering work will probably be on payloads, as opposed to platforms. For airplane engineers, the stress will probably be on versatility, rather than excellence in a narrow specialty. For electronic engineers, the stress is likely to be on sensors, on control, on data processing by microprocessors, and on man-machine interfaces, including the displays used in remote piloting. The supporting structure for precision weapons--reconnaissance, keeping track of targets, command and control--will doubtless get the engineering emphasis it deserves, and this will affect employment patterns.

Tank tactics will probably concentrate on the rapid offensive thrust, de-emphasizing the recent stress on the role of tanks defending against other tanks. This may mean that fewer main battle tanks will be needed. Because of the need to avoid being seen, sizes -- especially heights -- are likely to come down, forcing a move away from heavy, bulky turrets and stabilization gear which has been needed to work with heavy guns. Tank main guns may be made lighter through new technology or may dispense with high accuracy out the muzzle through using terminally guided munitions. There will be a premium on cutting crews below the four-man level, which requires an internal volume of about 16 cubic meters. Observers will watch with interest developments following the Swedish "S" tank, with its gun fixed to the chassis, and a height two-thirds that of the U.S. M-60.

In general there will be a trend toward designing platforms separate from weapons system payloads. Nowhere will this be more useful than in naval vessels, where economy has been forcing a full 30-year life from platforms, while weapon systems obsolesce much more rapidly. Fortunately new electronics technology is well-suited to modular construction, and for many jobs components can be sized to fit into standard boxes, power drain and heat dissipation requirements kept low, and input-output protocols easily adapted.

For the same reasons, many weapon systems will probably come to be made of standardized building blocks (as is airline practice with ARINC specifications) which will permit longer production runs of modules, by contrast with very short runs of tightly interwoven platforms and weapons systems. This kind of design will greatly facilitate international agreements on cooperative arms procurements -- but getting the rules worked out promises to be a formidable task for technical diplomacy!

SPECULATIONS ON THE BROADER IMPLICATIONS

Again I warn the reader to note the various qualifications, omissions, and uncertainties mentioned along the way. Subject to that warning, six overall points may be stated.

First, the prospects for increased stability over the short run, as non-nuclear PGMs make both smaller states and NATO more defensible, seem encouraging.

Second, an important consequence of the dispersal of so much destructive power down to small units, and the natural delegation of authority to use it, is that the pace of war will be faster. In places with large concentrations of forces there will be an unprecedented intensity of non-nuclear conflict. Even though, as noted earlier, the total weight of munitions to do a job may decrease over the entire time of the conflict, the *rate* of use -- in terms of fraction of stocks* consumed--is likely to go up. The material destroyed on both sides *per day of fighting* is likely to be an order of magnitude greater than we have been thinking about for non-nuclear war. We had a glimpse of this in the sudden logistic demands of the October 1973 war; a war in Europe could dwarf those consumption rates. Will this pace lead to escalation or to negotiation, as forces find munitions and equipment largely spent after three or four days of conflict?

Third, there is a hopeful sign that the trend of the first part of this century toward the inclusion of non-military target systems and civilian populations in military campaigns will be reversed. Precision

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*The assumption here is that the initial stock level of PGMs was fairly well matched to the task at hand in the sector under consideration.

delivery means that military targets can be destroyed with less total explosive power and less collateral damage to non-military targets. The faster pace discussed above means that tactical forces-in-being, as well as strategic forces, count more, and the general economy less, in achieving a favorable outcome.

Fourth, the pervasive changes in posture which PGMs are bringing about among the major powers suggests that this is a good time to revise theater nuclear policies -- which are now so vague as to be dangerous. Precision delivery of nuclear weapons is conducive to their better protection and closer control, while the effectiveness of precisely delivered non-nuclear weapons makes the uncertainties of nuclear use much more avoidable.

Fifth, dissatisfaction with the central role in strategy of an almost unbelievable threat of assured nuclear destruction has been growing in the West, while Soviet capabilities to make limited use of nuclear force have increased. Precision weapons will clearly play an important part in making, or countering, a threat to use nuclear force in a limited way. Analysts are beginning to understand the mechanics of these new ways to use force -- which may be very important for years to come. But no one understands well how to forecast the sequence of moves that may result from actual nuclear use.

Sixth, and finally, there is a major build-up of arms underway in the Middle East. The increasingly wealthy oil producing countries are not confining their purchases to PGMs, nor to defensive weapons. The prospects for restraint on the part of the major arms producing countries are dim indeed, given the economic imperatives. This is a problem which deserves the creative attention of all who are concerned with national security and world stability.

SUGGESTED READING

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